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THE PHYSICAL WORK ENVIRONMENT ASSESSMENT IN MANUFACTURING PROCESS BASED ON THE DISCOMFORT ANALYSIS (A Case Study at PT. SINAR TERANG LOGAMJAYA BANDUNG)

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ABSTRACT

The physical work environment comfort is become a prerequisite in a company development to increase productivity and company efficiency, and also gives motivation to workers to increase their performance. It is needs to conduct an assessment on physical work environment in the company.

Discomfort Analysis reveals 18 body members was involved, from head to feet, Based on signification test, it can be concluded that generally a company physical work environment is still comfort to workers, and there is no difference in work discomfort proportion to working hour evolution, whether at first hour, 4 hours work, or 8 hours work.

Key words : discomfort, evolution of discomfort, physical work environment

1. INTRODUCTION

1.1. Research Background

In system work design, many factors were integrated to gain a good work system, which are men, materials, money, and methods. Adjustment had to done by a company to create comfort physical work environment in order to workers can do their job properly and to reduce fatigue and muscle pain so that workers increase their performance and high productivity.

Accident is one of indicator to see physical work environment discomfort level. This would not happen if the company anticipate fatigue or muscle pain during works. Anticipation was done by every component in a company through adjustment among workers, processes, and physical work environment to man ability along the interaction with technology and machines.

Ergonomic review to physical work environment comfort is need to increase work performance

1.2. Research Identification

As mentioned in problem background, then the problem identifications are as follows,

1. How far the human body as a result of physical work environment discomfort which is felt by workers.
2. How far physical work environment discomfort effects to work hour evolution

1.3. Objectives

The research goals are as follows,

1. Find reasons factor felt by worker to physical work environment discomfort at the company
2. Find influence of physical work environment discomfort to work hour evolution

2. THEORITICAL BACKGROUND

2.1. Human–machine systems

A system is a set of elements, the relations between these elements and the boundary around them. Most systems consist of people and machines and perform a function to produce some form of output. Inputs are received in the form of matter, energy and information. For ergonomics, *the human is part of the system* and must be fully integrated into it at the design stage. Human requirements are therefore system requirements, rather than secondary considerations and can be stated in general terms as requirements for: (Bridger, 2003)

- Equipment that is usable and safe

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- Tasks those are compatible with people's expectations, limitations and training
- An environment that is comfortable and appropriate for the task
- A system of work organization that recognizes people social and economic needs.

Ergonomics is the study of the interaction between people and machines and the factors that affect the interaction. Its purpose is to improve the performance of systems by improving human machine interaction. This can be done by designing-in' a better interface or by designing-out' factors in the work environment, in the task or in the organization of work that degrade human–machine performance.

All work systems have a physical or functional boundary around them that separates them from adjacent systems. *Systems analysis* is the name of the discipline that studies the structure and function of work systems and provides the means by which simple systems may be combined to form more complex systems. Systems analysis is an integral part of all advanced work in ergonomics.

The human body is part of the physical world and obeys the same physical laws as other animate and inanimate objects. The goal of ergonomics at this level is to optimize the interaction between the body and its physical surroundings. This means ensuring that physical space requirements are met (using data on human anthropometry') and that internal and external forces acting on the body are not harmful. Ergonomic problems often arise because, although the operator is able to carry out the task, the effort required overloads the sustaining and supportive processes of the body and causes fatigue, injury or errors. This refers to the place and the circumstances in which work is carried out and consists of the physical workspace, the physical environment and the social and technical constraints under which the work is done. Many aspects of the physical environment can effect workers. Ergonomists are most interested in those that have an influence on the way the human and machine components interact. Noise, vibration, lighting and climate are of most concern to the ergonomist. Contamination and pollution of the environment are matters best dealt with by industrial hygienists, because they presumably have direct effects on health irrespective of any other work system factors. However, an awareness of these aspects is also important from an ergonomic perspective because they may have effects on human abilities and motivation as well as on health.

2.2. Design of the Work Environment

The two major components of the work environment that effect the behavior of a human-machine systems are the physical environment and the social environment (Pulat, 1992). Elements of the social environment include isolation, task pressure, group dynamics, and the like. Although human performance has been studied and reported under a variety of environmental factors, the ones that most concern an industrial ergonomist are the physical factors that exist in industrial environments, such as illumination, noise, vibration, and ambient temperature (heat and cold). However, the visual environment, noise, vibration, and ambient temperature are the physical environmental stressors that are most important in industry. For best human performance and minimal effects on the body, their levels must be kept within comfortable ranges. The immediate physical environment has a significant impact not only on the operator's and supervisor's performance, but also on reliability of the process (Niebel, 1988). The principal environmental factors that influence the productivity of the working personnel and dependability of the process include the visual environment, noise, vibration, humidity, temperature, bad atmospheric contaminants.

Despite automation and computerization of work, Work-related Musculoskeletal Disorders (WMSDs) are still prevalent in society. Repetitive work is common. The characteristics of the person, including age and skill level, can interact with the requirements of tasks and the design of tools, leading to excessive demands being placed on the musculoskeletal system.

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Neck and shoulder strain can be reduced at work by appropriate design of the visual requirements of tasks. Any beneficial effects are likely to be greater in older workers, where the background prevalence is higher and symptoms and more likely to be amplified by task-induced stress. Muscle and tendon problems such as cramp, tenosynovitis and tendonitis have been shown to be associated with highly repetitive activities. Musculoskeletal stress can be reduced and the efficiency of task performance increased by careful task and tool design (Bridger, 2003). Researchers have recently become interested in problems of the wrist, elbow and shoulder and a number of well-documented syndromes exist that are often, but not always, associated with work activities.

2.3. Industrial Safety and Health

Industrial safety deals with hazard recognition and control with respect to acute or instantaneous cases, such as sudden release of energy and possible injury or fatality due to it. A fall, or getting a hand stuck between reciprocating machine parts, are examples. Industrial health deals with hazards that show cumulative effects. A natural result of health hazards is illness. The worker/ task/ environment/ equipment/ organization system generally functions with no accidents. The reasons for accidents may be simple or complex. Sometimes a simple unsafe act such as not operating a control when it is required to do so may lead to an accident. Unsafe conditions that relate to the task, the environment, the equipment, and the organizational structure also may cause accidents. However, usually a combination of unsafe acts and unsafe conditions leads to incidents, which may cause a near accident or an accident. If an accident occurs, there may be only material damage or there may be physical harm to a worker or both.

Not only the working conditions, but also the personnel act must be controlled for the total job to be safe (Pulat, 1992). In general, a significant portion of the blame goes to the worker after an accident. One may argue that all accidents are due to unsafe acts. A person who designs and builds a machine that is not safe to operate is committing an unsafe act. However, the person who selects that equipment for use in the production process is also responsible. Equipment may be safe for use in certain conditions and unsafe others. Hence situational factors also play a role in determining whether or not an accident will occur.

3. RESEARCH METHOD

3.1. Modeling

Problem solving model in this research is physical work environment assesment based on discomfort questionnaire which developed by Ergofellow software (FBF Sistemas, 2009). Questionnaire involves 18 body members (head to feet) which is felt by workers/operators as a cause of physical work environment comfort ability or physical work environment discomfort ability. There are two parts of Discomfort questionnaire,

1. Frequency of Discomfort, frequency of physical work environment discomfort felt by operators.
2. Evolution of Discomfort, process of physical work environment discomfort measured from 1 hour as job begins, 4 hours work (begin to break), and 8 hours work (end of work).

Figure 1 is showing 18 body members involves

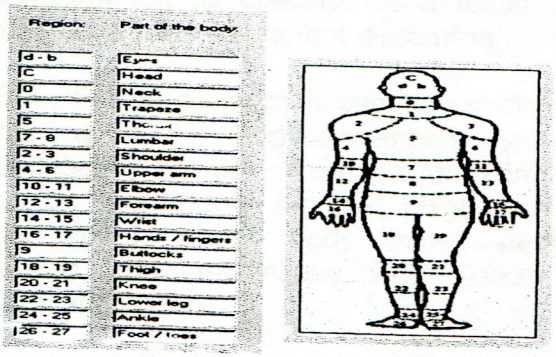

Fig. 1. Body members in Physical Work Environment Assessment.

3.2. Problem Solving

1. Discomfort Questionnaire Deployment

Questionnaire is deployed to operators in manufacture process division and to be filled by operators about discomfort during works.

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2. Frequency of Physical Work Environment Discomfort

Likert scale was used in questionnaire (1 – 5). If the score is greater or same than 3, then physical work environment is discomfort, otherwise if score is less than 3, then physical work environment is comfort.

Pareto diagram will be created to find out body members contribution percentage to physical work environment discomfort

3. Significance test to physical work environment discomfort

To see physical work environment discomfort effects to operators, statistical test was conducted to 2 categories, which are,

. Significance test to frequency of physical work environment

Using nonparametric test, sign test

) Hypothesis :

H_0 : Score average ≥ 3 (physical work environment was causing discomfort to operators).

H_1 : Score average < 3 (physical work environment was not causing discomfort to operators).

) Statistic Test :

$$Z = \frac{\bar{x} - \mu}{\sigma} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $\mu = n.p$; $\sigma = \sqrt{n.p.q}$; $q=1-p$ and $p = 0,5$

) Criteria: Reject H_0 if $Z < -Z_\alpha$.

. Significance test to effect of physical work environment to work hour evolution

To see effect of physical work environment felt by operators, 1 hour as begin to work, 4 hours work, and 8 hours work, statistical test, goodness of fit test, was used.

) Hypothesis :

H_0 : $p_{i1} = p_{i2} = \ldots = p_{ij}$ (there is no difference proportion of work discomfort to work hour evolution)

H_1 : at least one of proportion was different.

where i = 1, 2, 3, ..., r (r = number of body members involve); dan j = 1, 2, 3, ..., k (k = work hour evolution).

Statistical Test :

$$x^2 = \sum_{i=1}^{r} \sum_{j=1}^{k} \frac{(fij - eij)^2}{eij} \quad \ldots\ldots (2)$$

c) Criteria: Reject H_0 if $\chi^2 > \chi^2_{(\alpha)}$ with degree of freedom (ν)= (r–1).(k–1).

4. RESULT AND DISCUSSION

4.1. Population and Sample Size

Questionnaire was deployed to operators in manufacture process division as much 131 operators, and sample was drawn in this research was 100 operators. Estimated sample size was 77, in this case, number of drawn sample was greater than estimated sample, so that it can represent the population characteristic.

4.2. Frequency of discomfort

Figure 2 shows frequency of discomfort felt by 18 body members from 100 operators.

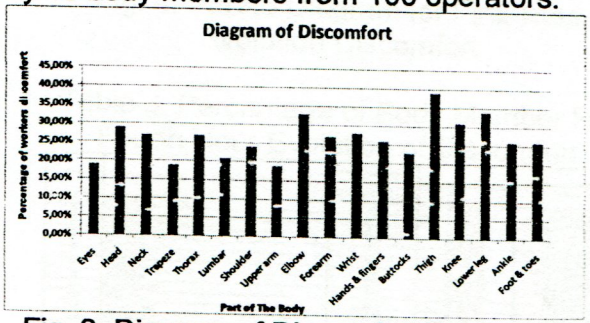

Fig. 2. Diagram of Discomfort Frequency for 18 Body Members

Table 1 and Figure 3 shows pareto diagram of body members which are dominant felt by operator as a result of physical work environment discomfort.

From Pareto diagram it can be conclude that dominant body members gives contribution to work discomfort as 62.97%, felt by operators in leg part (thigh, lower leg, knee), upper body (head, neck, thorax), and arm (elbow, wrist, forearm, hand and finger).

The tenth body members were dominant felt by operators as a result of physical work environment discomfort and were predicted will cause accident.

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Table 1. Percentage of Body Member for Frequency of Discomfort

No	Category of Body Member	Frequence of Discomfort	Percentage	Cummulative (%)
1	Thigh	39	8,16%	8,16%
2	Lower leg	34	7,11%	15,27%
3	Elbow	33	6,90%	22,18%
4	Knee	31	6,49%	28,66%
5	Head	29	6,07%	34,73%
6	Wrist	28	5,86%	40,59%
7	Neck	27	5,65%	46,23%
8	Thorax	27	5,65%	51,88%
9	Forearm	27	5,65%	57,53%
10	Hands & fingers	26	5,44%	62,97%
11	Ankle	26	5,44%	68,41%
12	Foot & toes	26	5,44%	73,85%
13	Shoulder	24	5,02%	78,87%
14	Buttocks	23	4,81%	83,68%
15	Lumbar	21	4,39%	88,08%
16	Eyes	19	3,97%	92,05%
17	Trapeze	19	3,97%	96,03%
18	Upper arm	19	3,97%	100,00%
	Total =	478		

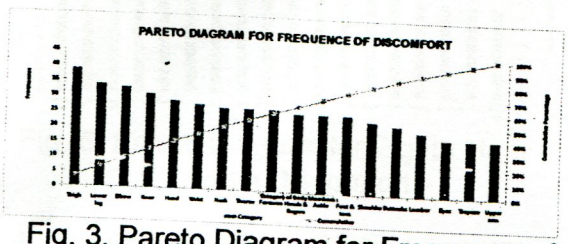

Fig. 3. Pareto Diagram for Frequency of Discomfort

At leg part, as a result of stand-up position will cause pain in thigh, lower leg, and knee.

At upper body part will cause headache due to noise and dust, and cause pain at neck as a result of continuity of concentration, and respiration problem due to welding smoke and dusty room.

At arm part, pain to arm as a result of heavy weight controlling and high frequency of fast moves will cause pain and joint dislocation at elbow, pain at forearm and hand and finger, and at wrist.

4.3. Evolution of Discomfort

Table 2 and figure 4 shows result of questionnaire evolution of discomfort felt by 18 body members measured by 1 hour, 4 hours, and 8 hours work.

According to figure 4, it can be conclude that dominant body members give 32.24% percentage of discomfort. Generally operators feel for the first hour work is muscle pain at buttock, thorax, head, and thigh.

Table 3 and Figure 5 show the result for 4 hours works.

Table 2. Percentage of Body Member for First Hour Evolution of Discomfort

No	Category of Body Member	Frequence of Discomfort	Percentage	Cummulative (%)
1	Buttocks	21	10,71%	10,71%
2	Thorax	15	7,65%	18,37%
3	Head	14	7,14%	25,51%
4	Thigh	13	6,63%	32,14%
5	Trapeze	12	6,12%	38,27%
6	Upper arm	12	6,12%	44,39%
7	Forearm	12	6,12%	50,51%
8	Knee	11	5,61%	56,12%
9	Ankle	11	5,61%	61,73%
10	Foot & toes	11	5,61%	67,35%
11	Neck	10	5,10%	72,45%
12	Lumbar	10	5,10%	77,55%
13	Lower leg	10	5,10%	82,65%
14	Elbow	9	4,59%	87,24%
15	Shoulder	8	4,08%	91,33%
16	Hands & fingers	7	3,57%	94,90%
17	Wrist	6	3,06%	97,96%
18	Eyes	4	2,04%	100,00%
	Total =	196		

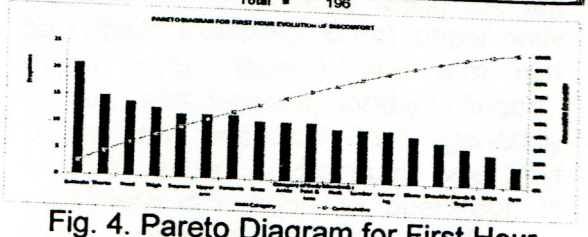

Fig. 4. Pareto Diagram for First Hour Evolution Discomfort

Tabie 3. Percentage of Body Member For Fourth Hour Evolution of Discomfort

No	Category of Body Member	Frequence of Discomfort	Percentage	Cummulative (%)
1	Foot & toes	28	7,50%	7,50%
2	Neck	26	7,05%	14,63%
3	Hands & fingers	24	6,50%	21,14%
4	Upper arm	23	6,23%	27,37%
5	Forearm	23	6,23%	33,60%
6	Wrist	23	6,23%	39,84%
7	Knee	23	6,23%	46,07%
8	Ankle	23	6,23%	52,30%
9	Lumber	21	5,69%	57,99%
10	Elbow	21	5,69%	63,68%
11	Thorax	19	5,15%	68,83%
12	Buttocks	19	5,15%	73,98%
13	Head	18	4,88%	78,86%
14	Thigh	18	4,88%	83,74%
15	Lower leg	18	4,88%	88,62%
16	Trapeze	15	4,07%	92,68%
17	Eyes	14	3,79%	96,46%
18	Shoulder	13	3,52%	100,00%
	Total =	369		

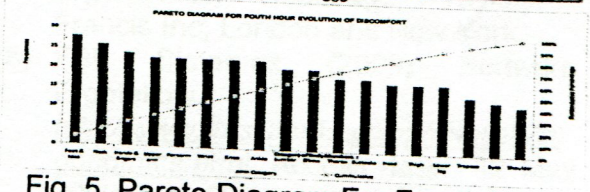

Fig. 5. Pareto Diagram For Fourth Hour Evolution Discomfort

From figure 5, it is concluded that dominant body members give contribution 27.37% to work discomfort. The operators feel discomfort during work at foot and toes, neck, hand and finger, and upper arm. At this period, operators usualiy have a little break to loosen their muscle.

From figure 6, it is concluded that dominant body members give contribution 27.37% to work discomfort. The operators feel discomfort during work at upper arm, elbow, hand and finger, and wrist. After this period, operators usually feel pain muscle

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or stirring muscle at upper arm, wrist, elbow, and hand and finger due to fast arm movement for 8 hours.

Table 5. Percentage of Body Member For Eighth Hour Evolution of Discomfort

No	Category of Body Member	Frequency of Discomfort	Percentage	Cummulative (%)
1	Upper arm	83	6,99%	6,99%
2	Elbow	81	6,77%	13,76%
3	Hands & fingers	86	6,10%	19,87%
4	Wrist	84	6,00%	25,86%
5	Thorax	82	5,72%	31,58%
6	Lumber	81	5,64%	37,22%
7	Eyes	80	5,58%	42,81%
8	Knee	80	5,58%	48,39%
9	Foot & toes	80	5,58%	53,97%
10	Ankle	79	5,51%	59,48%
11	Shoulder	78	5,44%	64,92%
12	Forearm	48	5,33%	70,25%
13	Thigh	48	5,33%	75,58%
14	Neck	47	5,33%	80,91%
15	Trapeze	45	4,99%	85,90%
16	Head	44	4,88%	90,78%
17	Buttocks	43	4,77%	95,55%
18	Lower leg	43	4,77%	100,00%
	Total =	1201		

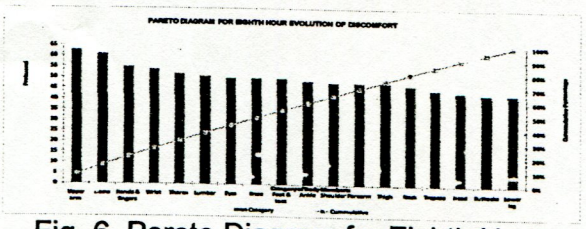

Fig. 6. Pareto Diagram for Eighth Hour Evolution Discomfort

4.4. Significance Test to Physical Work Environment Discomfort

There are 2 categories on this statistical test, which are,

1. Significance Test to frequency of Physical Work Environment Discomfort

This test was using nonparametric test, sign-test with α = 0.05, to 18 body members. The results are rejected H_0, that means physical work environment is still comfort to operators, as shown in Table 5

2. Significance Test to Effect on Physical Work Environment Discomfort Evolution to Work Hour

This test was using Chi-Square Goodness of Fit Test with α = 0.05, to see the effect on Physical Work Environment Discomfort Evolution to 1 hour work, 4 hours work, and 8 hours work. Test result is accept H_0, that mean there is no difference proportion of work discomfort to work hour evolution.

Table 5. The Sign-test

no	Body Members	n	value +	μ	σ	Z	Hypotesis Decision
1	Eyes	85	4	42,5	4,61	-8,24	rejectHo
2	Head	76	3	38	4,36	-7,46	rejectHo
3	Neck	83	10	41,5	4,56	-6,81	rejectHo
4	Trapeze	86	5	43	4,64	-8,09	rejectHo
5	Thorax	80	7	40	4,47	-7,27	rejectHo
6	Lumber	86	7	43	4,64	-7,66	rejectHo
7	Shoulder	84	8	42	4,58	-7,31	rejectHo
8	Upper arm	88	7	44	4,69	-7,78	rejectHo
9	Elbow	75	8	37,5	4,33	-6,70	rejectHo
10	Forearm	80	7	40	4,47	-7,27	rejectHo
11	Wrist	77	5	38,5	4,39	-7,52	rejectHo
12	Hands & fingers	87	13	43,5	4,66	-6,43	rejectHo
13	Buttocks	83	6	41,5	4,56	-7,68	rejectHo
14	Thigh	75	14	37,5	4,33	-5,31	rejectHo
15	Knee	81	12	40,5	4,50	-6,22	rejectHo
16	Lower leg	76	10	38	4,36	-6,31	rejectHo
17	Ankle	79	5	39,5	4,44	-7,65	rejectHo
18	Foot & toes	85	11	42,5	4,61	-6,72	rejectHo

Note : Zα =0,05 = 1,96

5. CONCLUSION

1. Dominant body members is felt by operator was the effect of physical work environment discomfort, which are leg part (thigh, lower leg, knee), upper body (head, neck, thorax), and arm part (elbow, wrist, forearm, hand and finger).
2. Based on statistical test, generally physical work environment was not significant discomfort to operators, in other words, there is no difference proportion of work discomfort to work hour evolution.
3. As a result of this paper, it is known that body member can cause work discomfort to workers. The company must have anticipate this matters to reduce work accident.

6. REFERENCES

(a) Bridger, R.S (2003) *Introduction to Ergonomics*, Routledge, Taylor & Francis Inc, London and New York.

(b) FBF Sistemas (2009) Software Ergofellow. http://www.fbfsistemas.com/english/ergonomics.html. Access date : 12 May 2009 at 10.00.

(c) Niebel, Benjamin W. (1988) *Motion and Time Study*, Irwin Inc, Homewood, Illinois, USA.

(d) Pulat, B Mustafa (1992) *Fundamentals Of Industrial Ergonomics*, Prentice Hall. Englewood Cliffs, New Jersey.